


LiDAR QA/QC  
- Quantitative and Qualitative Assessment report -

CT T0009\_LiDAR  
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Submitted to:  
Roald Haested Inc.  
Prepared by:  
 **Dewberry**  
Fairfax, VA

## EXECUTIVE SUMMARY

This LiDAR project covered approximately 40 sq miles along the coastline of Connecticut and was acquired in December of 2006 providing a mass point dataset with an average point spacing of 3 ft. The data is tiled, stored in LAS format and LiDAR returns are classified in 2 classes: ground and non-ground.

Dewberry's Fairfax office performed a quality assessment of these data including a quantitative and a qualitative assessment.

First, the elevation exceeds the accuracy required for this project (accuracy equivalent to 2 ft contours according to FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners*). Compared with the Fundamental Vertical Accuracy specification of 1.19 ft, these data were tested 0.33 ft fundamental vertical accuracy at 95 percent confidence level in open terrain using RMSE x 1.96 on 80 survey points.

Secondly, every tile was reviewed at the macro level for data completeness; all tiles were delivered, no remote-sensing data voids were found and data are free of systematic errors. The cleanliness of the bare earth model was assessed on 20% of the tiles at the micro level and exhibits excellent quality. Minor errors were found (like cornrows and possible vegetation remains) but are not representative of the majority of the data.

In essence, this LiDAR dataset is of outstanding quality and meets the needs of FEMA and FEMA contractors for flood mapping.

Breaklines were acquired over streams, lakes and coastline using existing orthophotos to establish hydrological features in the terrain model. These breaklines are 3D lines and were used with a 15 ft gridded version of the ground LiDAR points to generate 2 ft engineering type contours.

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## **LIDAR QA/QC REPORT**

### **1 Introduction**

LiDAR technology data gives access to precise elevation measurements at a very high resolution resulting in a detailed definition of the earth surface topography. As a consequence of this precision, millions of points with potential measurement and processing accuracy issues must be verified. This constitutes a challenge for the quality assessment aspect. Dewberry's expertise is in provision of both quantitative and qualitative evaluations of the LiDAR mass points and their usability for flood mapping.

Quantitative analysis addresses the quality of the data based on absolute accuracy of a limited collection of discrete checkpoint survey measurements. As the accuracy is tested in several land cover types (open terrain, woods/crops, forested, and urban areas) but always at ground level, the classification accuracy is indirectly evaluated, i.e. LiDAR ground points will fit survey ground points in vegetated areas only if the vegetation is correctly removed by classification and if the LiDAR penetrated the canopy to the ground. Although only a small amount of points are actually tested through the quantitative assessment, there is an increased level of confidence with LiDAR data due to the relative accuracy. This relative accuracy in turn is based on how well one LiDAR point "fits" in comparison to the next contiguous LiDAR measurement as acquisition conditions remain similar from one point to the next.

To fully address the data for overall accuracy and quality, a qualitative review for anomalies and artifacts is conducted based on the expertise of Dewberry's analysts. As no automatic method exists yet, we perform a manual visualization process. This includes creating pseudo image products such as 3-dimensional models. By creating multiple images and using overlay techniques, not only can potential errors be found, but we can also find where the data meets and exceeds expectations.

Within this Quality Assurance/Quality Control process, three fundamental questions were addressed:

- Was the data complete?
- Did the LiDAR system perform to specifications?
- Did the ground classification process yield desirable results for the intended bare-earth terrain product?

The first part of this report presents the QA/QC process and results. Then, the methodology used to generate the 2 ft contours from the LiDAR data using the supplemental breaklines will be explained.

## 2 Quality Control

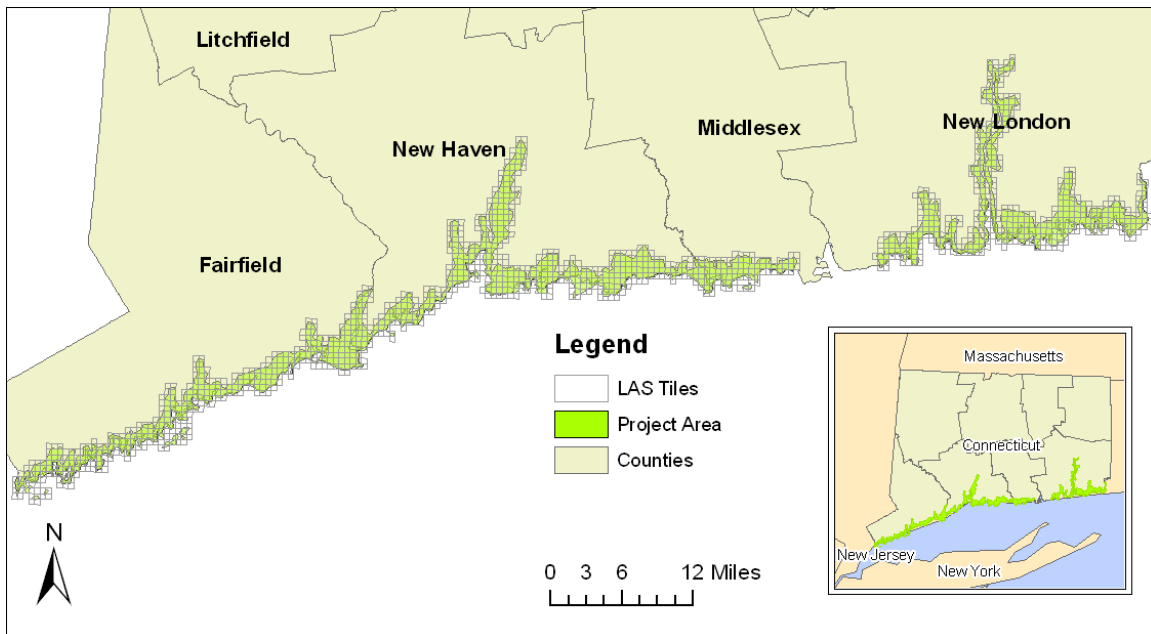
### 2.1 Completeness of LiDAR deliverables

Once the data are acquired and processed, the first step in our review is to inventory the data delivered, to validate the format, projection, georeferencing and verify if elevations fall within an acceptable range.

#### 2.1.1 Inventory and location of data

The project is separated in 2 areas along the coastline of Connecticut (illustrated in Figure 1)

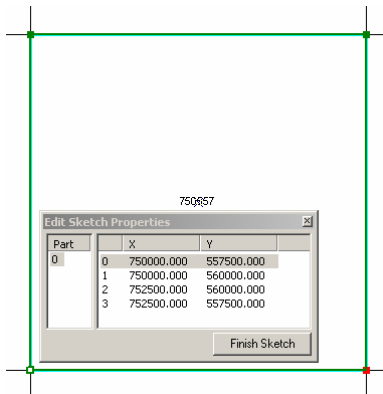
- Coastline of Fairfield county (50.3 sq miles), New Haven county (65 sq miles), Middlesex county (except east part, 11 sq miles)
- Coastline of New London county (60 sq miles except west part)



**Figure 1 – Mapping areas**

Data were acquired in fall 2006 during leaf-off and before snow at low tide conditions. The data average point spacing is 3 ft.

The tile scheme is built on square tiles of 2,500 x 2,500 ft each, the tile number is based on the 3 first digits of the tile's lower left corner coordinates in State Plane feet – Connecticut, i.e. the corner of tile 750557 has (750000, 557500) as coordinates (see Figure 2).



**Figure 2 – Tile scheme**

A total of 1407 files were provided covering the entire required area. Data were delivered in LAS format version 1.0, each record includes the required class code (code1 for non-ground and code 2 for ground) along with additional information like: flightline number, intensity, return number. Although the initial Scope of Work stated that the data should be in LAS 1.1 this was not possible as the LiDAR system is only capable of collecting data and storing it as LAS1.0. It should be noted that the 1.0 format basically provides the same information and no data integrity is lost.

Although the LAS file header does not include a projection definition, it was verified that the spatial reference for the data is:

- Projection: State Plane - Connecticut
- Horizontal Datum: NAD83
- Vertical Datum: NAVD88
- Units: US Survey Feet

### **2.1.2 Statistical analysis of tile content**

To verify the contents of the data and to validate the data integrity, a statistical analysis was performed on all the data. This process allows us to statistically review 100% of the data to identify any gross outliers. This statistical analysis consists of:

1. Extract the header information (number of points, minimum, maximum, elevation)
2. Compare the LiDAR file extent with the tile extent

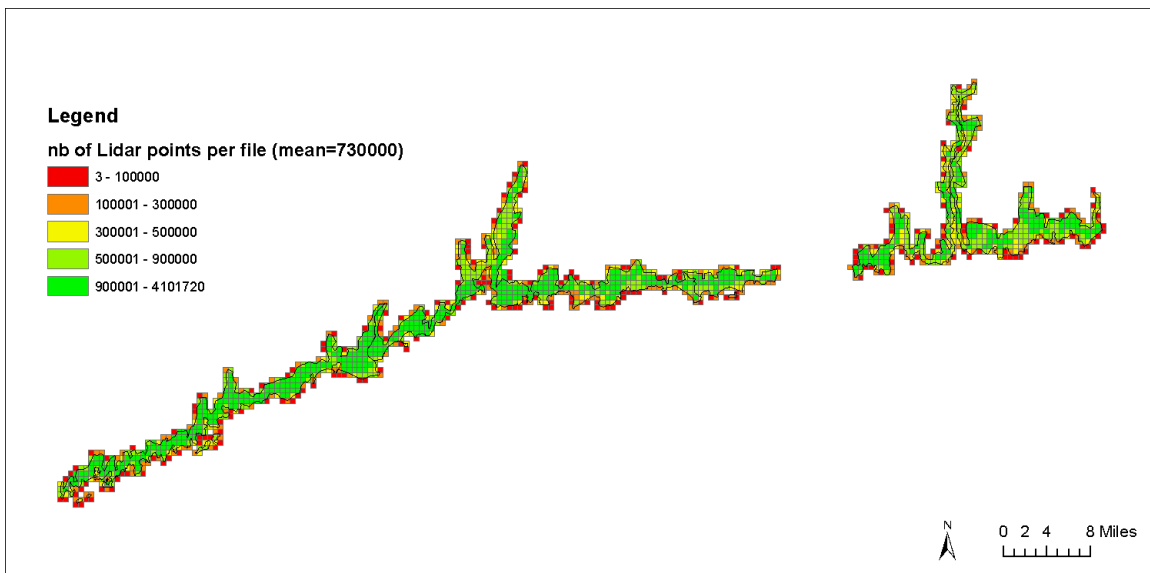
Each tile was queried to extract the number of LiDAR points and all tiles are within the anticipated size range, except for where fewer points are expected (because of water features or near the project boundary). Figure 3 presents a map of the number of records in each LAS files (full point cloud), highlighting tiles with less than 100,000 points.

Additionally the minimum and maximum elevation values in each file were computed and mapped. It can be noticed on Figure 4 that a majority of the files have z min values between -5ft and -1feet, for the most part over water bodies. Besides, users should be aware that as the contract for acquisition and processing identified only two classes: Class “1” for unclassified and Class “2” for ground, there is no distinction for water and

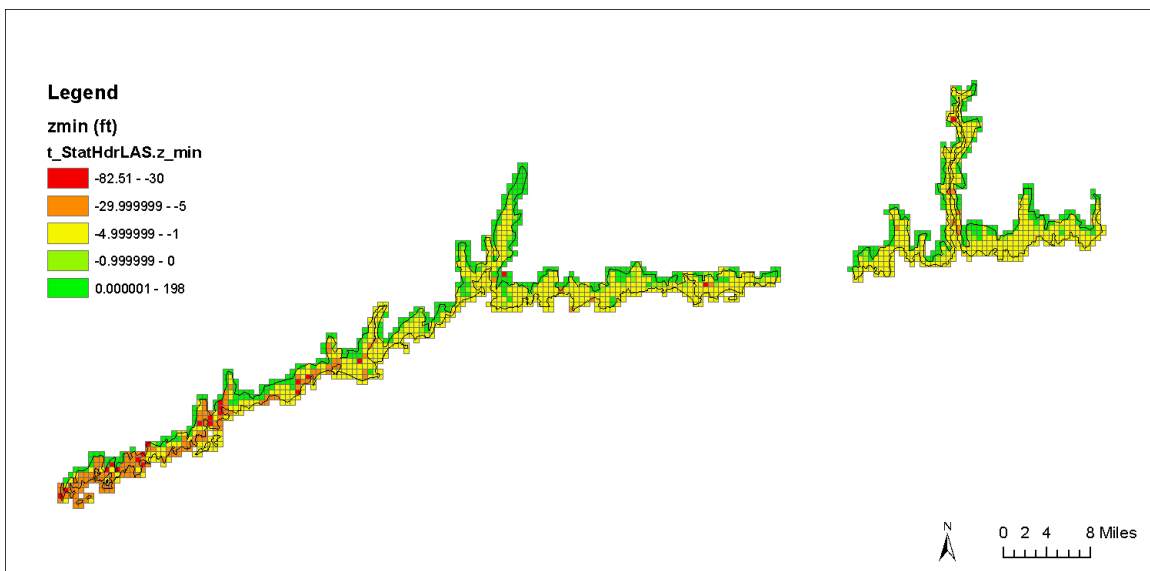
therefore some water points may be classified as ground if the water elevations are equal to that of the surrounding terrain.

Two files having z maximum values above 3000 ft (Figure 5) exhibits spikes but these points are not classified as ground.

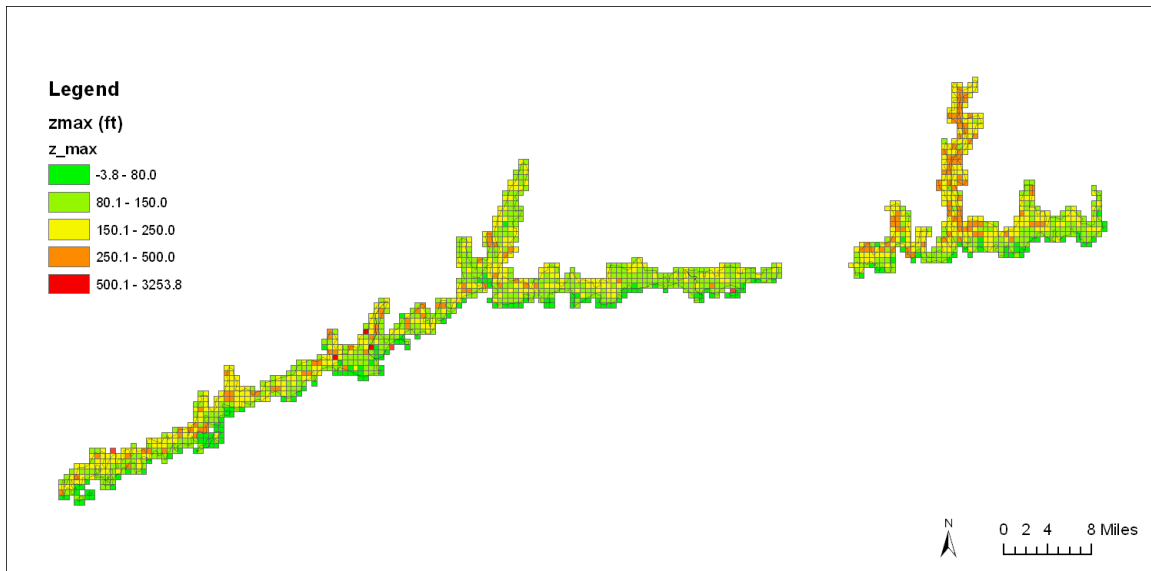
The geographic extent of the LAS files were compared to the extent of the tiles. This process ensures that the data within the LAS file is spatially contained within the extents of each corresponding tile boundary. Figure 6 shows that files were truncated along the project boundary and this correlates with smaller number of points in Figure 3. Moreover, we verified that all the files are located within the tile extents.



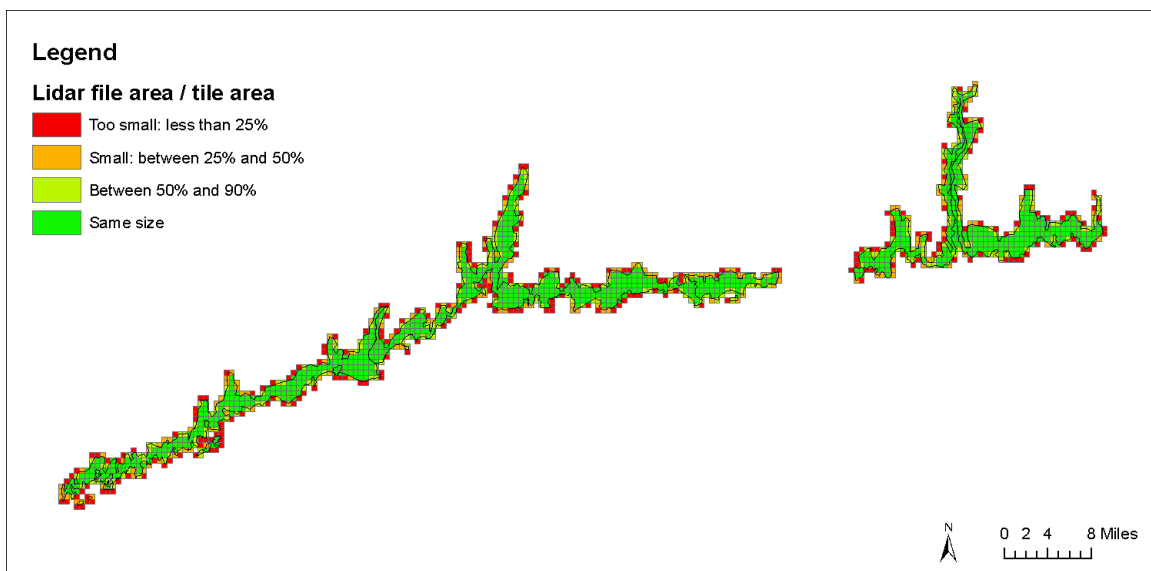
**Figure 3 - Number of records in LAS files located by tiles.**



**Figure 4 – Minimum elevation in each LAS file**



**Figure 5 - Maximum elevation in each LAS file**



**Figure 6 – Comparison between the LiDAR file extent and the tile extent**

This general overview of the data allows us to assess that all the data were delivered as expected and that the majority of the files shows an acceptable range of values except for a few isolated non-critical anomalies. Further quality assessment is needed to investigate the individual quality of each file.

### 3 Quality Assurance

#### 3.1 Quantitative assessment

##### 3.1.1 Inventory of survey points

A quantitative analysis of the accuracy has been conducted on the data using 80 check points distributed in 4 land cover types (open terrain, weeds/crops, forest, urban). These



survey checkpoints were provided to Dewberry from Roald Haestad Inc. collected under the guidance from Dewberry. A list can be found in Appendix A and the complete field survey report from Roald Haestad Inc. is provided with the data.

### 3.1.2 Vertical Accuracy: elevation comparison

Using the ground truth checkpoint survey as the reference, the elevation at the same x and y positions were interpolated from the LiDAR data. The method used to extract the elevation from the LiDAR mass points at a given location was to create a triangular irregular network (TIN) from the ground classified points and to interpolate the elevation at the given x and y coordinates using the 3 nearest LiDAR neighboring points. To compare the two types of measured elevations, statistics were then computed following two different guidelines further explained in the following sections.

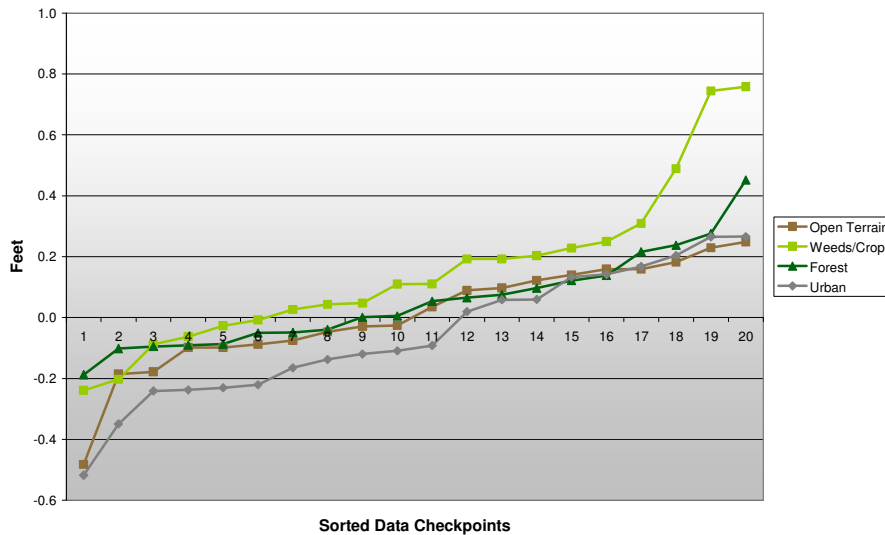
### 3.1.3 Vertical Accuracy Assessment Using the RMSE Methodology

The first method of testing vertical accuracy used the FEMA specifications which essentially follows the NSSDA procedures. The accuracy is reported at the 95% confidence level using the Root Mean Square Error (RMSE) which is valid when errors follow a normal distribution. This methodology measures the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. The vertical accuracy assessment compares the measured survey checkpoint elevations with those of the TIN as generated from the bare-earth LiDAR. The survey checkpoint's X/Y location is overlaid on the TIN and the interpolated Z value is recorded. This interpolated Z value is then compared to the survey checkpoint Z value and this difference represents the amount of error between the measurements.

The following tables and graphs outline the vertical accuracy and the statistics of the associated errors. Figure 7 illustrates the distribution of the elevation differences between the LiDAR data and the surveyed points by land cover type and sorted from lowest to highest. Points in weeds and crops tend to have the highest errors and both vegetated categories have a positive bias (majority are positives). This means that the elevation interpolated from the LiDAR dataset is higher than the surveyed point. This could be explained by a non-penetration of the LiDAR beam all the way through the ground or by a misclassification of some points actually belonging to the vegetation class. However, all the differences largely remain within acceptable ranges, and do not constitute an issue.

**Table 1 – Descriptive statistics (FEMA guidelines) by land cover category**

100 % of Totals	RMSE (ft) Spec=0.61ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Consolidated	0.22	0.04	0.04	0.55	0.22	80	-0.52	0.76
Open Terrain	0.17	0.01	0.00	-1.01	0.18	20	-0.48	0.25
Weeds/Crop	0.30	0.11	0.03	0.99	0.27	20	-0.24	0.76
Forest	0.16	0.05	0.03	0.89	0.16	20	-0.19	0.45
Urban	0.22	-0.06	-0.10	-0.22	-0.22	20	-0.52	0.27



**Figure 7 - Elevation differences between the interpolated LiDAR and the surveyed QA/QC checkpoints**

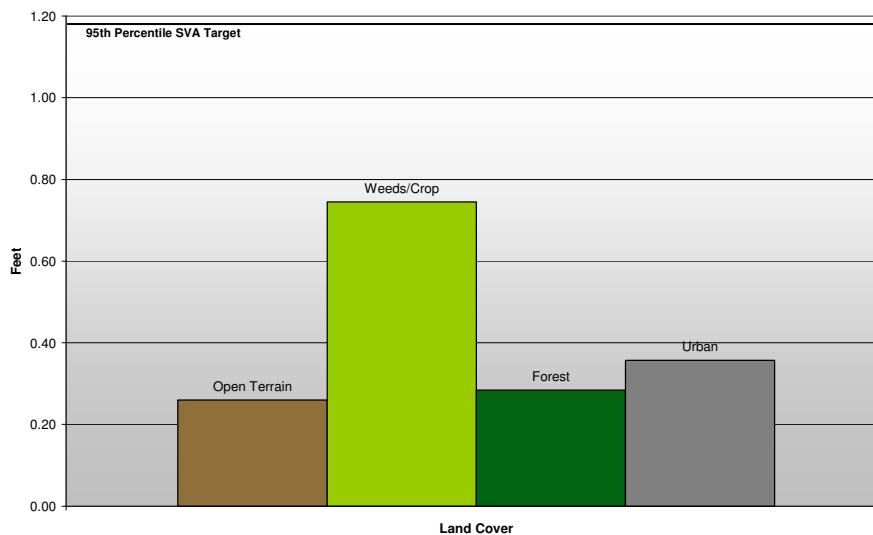
### 3.1.4 Vertical Accuracy Assessment Using the NDEP Methodology

The RMSE method assumes that the errors follow a normal distribution, and experience has shown that this is not always the case as vegetation and manmade structures can limit the ground detection causing errors greater than in unobstructed terrain. The NDEP methodology therefore assumes that the data does not follow a normal distribution and tests the open terrain (bare-earth ground) separately from other ground cover types.

The *Fundamental Vertical Accuracy* (FVA) at the 95% confidence level equals 1.96 times the RMSE in open terrain only (as previously explained: the RMSE methodology is appropriate in open terrain). *Supplemental Vertical Accuracy* (SVA) at the 95% confidence level utilizes the 95<sup>th</sup> percentile error individually for each of the other land cover categories, which may have valid reasons (e.g. problems with vegetation classification) why errors do not follow a normal distribution. Similarly the *Consolidated Vertical Accuracy* (CVA) at the 95% confidence level utilizes the 95<sup>th</sup> percentile error for all land cover categories combined. This NDEP methodology is used on all 100% of the checkpoints

**Table 2 – Accuracy using NDEP methodology**

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSE <sub>z</sub> x 1.9600) Spec=1.19 ft	CVA — Consolidated Vertical Accuracy (95 <sup>th</sup> Percentile) Spec=1.19 ft	SVA — Supplemental Vertical Accuracy (95 <sup>th</sup> Percentile) Target=1.19 ft
Consolidated	80		0.483	
Open Terrain	20	0.336		0.260
Weeds/Crop	20			0.745
Forest	20			0.284
Urban	20			0.358



**Figure 8 - 95th Percentile by Land Cover Type**

The target objective for this project was to achieve bare-earth elevation data with an accuracy equivalent to 2 ft contours, which equates to an RMSE of 0.61 ft when errors follow a normal distribution. With these criteria, the Fundamental Vertical Accuracy of 1.19 ft must be met. Furthermore, it is desired that the Consolidated Vertical Accuracy and each of the Supplemental Vertical Accuracies also meet the 1.19 ft criteria to ensure that elevations are also accurate in vegetated areas. As summarized in Table 2, this data:

- Does satisfy the NDEP's mandatory Fundamental Vertical Accuracy criteria for 2 ft contours.
- Does satisfy the NDEP's targeted Supplemental Vertical Accuracy criteria for 2 ft contours.
- Does satisfy the NDEP's mandatory Consolidated Vertical Accuracy criteria for 2 ft contours.

### **3.1.5 Vertical Accuracy Conclusion**

Utilizing both methods of vertical accuracy testing, this data meets and exceeds all specifications. The consolidated RMSE of 0.22 ft is less than the FEMA requirement of 0.61ft. This data is of excellent quality and should satisfy most users for high accuracy digital terrain models.

## **3.2 Qualitative assessment**

### **3.2.1 Protocol**

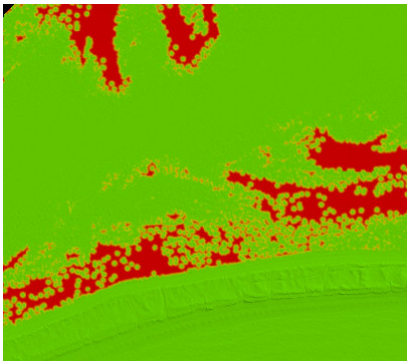
The goal of this qualitative review is to assess the continuity and the level of cleanliness of the data. The acceptance criteria we have reviewed are the following:

- If the density of points is homogeneous and sufficient to meet the user needs,
- If the ground points have been correctly classified (no manmade structures and vegetation remains, no gap except over water bodies),

- If the ground surface model exhibits a correct definition (no aggressive removal, no over-smoothing, no inconsistency in the post-processing), in a context of flood modeling, special attention is given to stream channels,
- If no obvious anomalies due to sensor malfunction or systematic processing artifact are present (data holidays, spikes, divots, ridges between tiles, cornrows...).

Dewberry analysts, experienced in evaluating LiDAR data, performed a visual inspection of the bare-earth digital elevation model (bare-earth DEM). LiDAR mass points were first gridded with a grid distance of two times the full point cloud resolution. Then, a TIN was built based on this gridded DEM and is displayed as a 3D surface. A shaded relief effect was applied, which enhances 3D rendering. The software used for visualization allows the user to navigate, zoom, rotate models and to display elevation information with an adaptive color coding in order to better identify anomalies.

One of the variables established when creating the models is the threshold for missing data. For each individual triangle, the point density information is stored. If it meets the threshold, the corresponding surface will be displayed in green, if not it will be displayed in red (see Figure 9).



**Figure 9 – Ground model with density information (red means no data)**

The first step of our qualitative workflow was therefore to verify data completeness and continuity using the bare-earth DEM with density information, displayed at a macro level. If, during this macro review of the ground models, we find potential artifacts or large voids, we use the digital surface model (DSM) based on the full point cloud including vegetation and buildings to help us better pinpoint the extent and the cause of the issue. Moreover, the intensity information stored in the LiDAR data can be visualized over this surface model, helping in interpretation of the terrain.

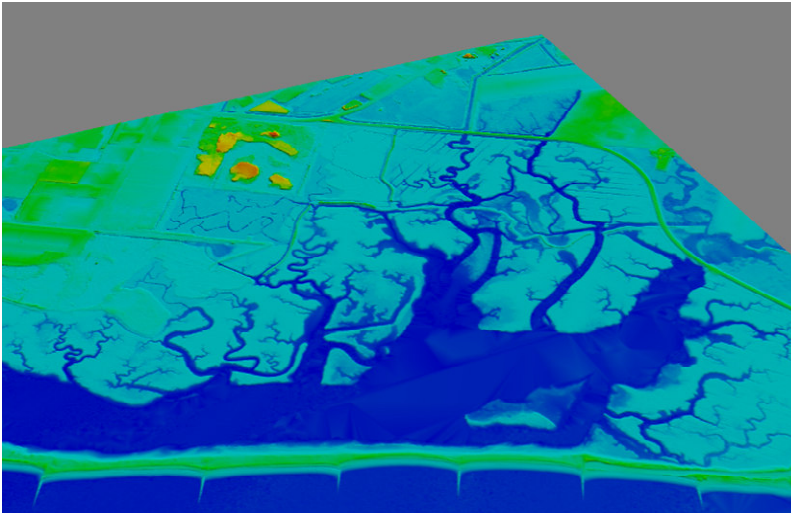
Finally, in case the analyst suspects a systematic errors relating to data collection, a visualization of the 3D raw mass points is performed, rather than visualizing as a surface. This particular type of display helps us visualize and better understand the scan pattern and the flight line orientation.

The process of importing, comparing and analyzing these two later types of models (DSM with intensity and raw mass point), along with cross section extraction, surface measurements, density evaluation, constitutes our micro level of review.

### 3.2.2 Quality report

We reviewed all the tiles at a macro level, and 20% at a micro level.

Overall, the data are consistent and of excellent quality, no data voids and no major anomalies were found. The bare earth product exhibits a precise definition of all hydro features as illustrated in Figure 10.



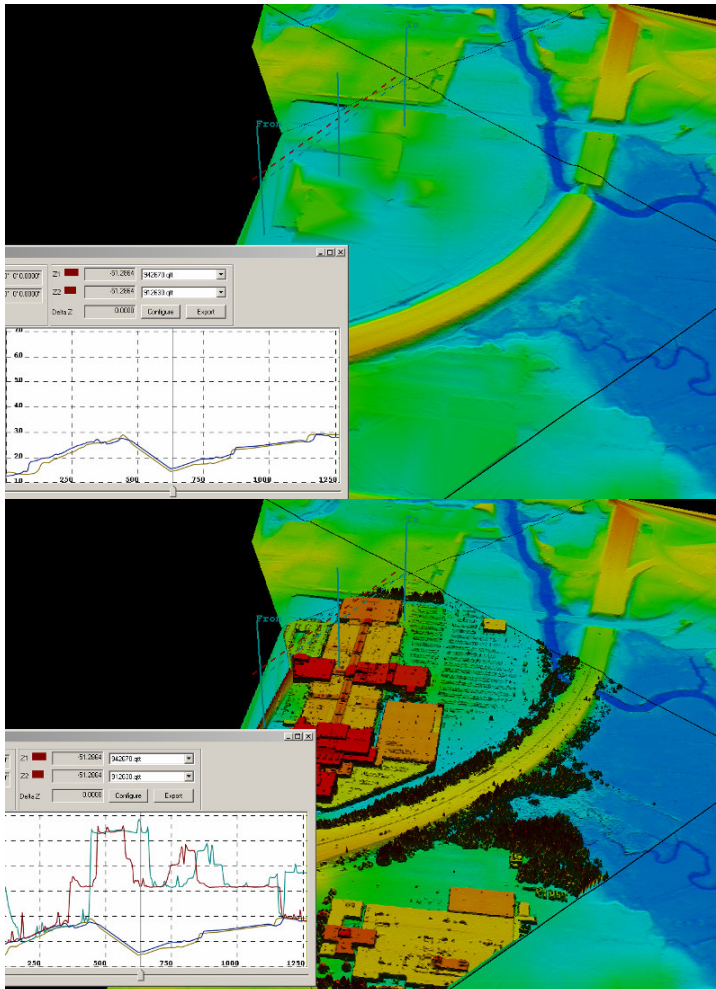
**Figure 10 – Tile 892617; excellent example of the topographic definition**

The project contained very few errors in the data; all issues are common with LiDAR data and are within acceptable limits. Contact sheets of all the errors found during the review are given in Appendix B). These errors are minor and not serious enough to render the data unusable.

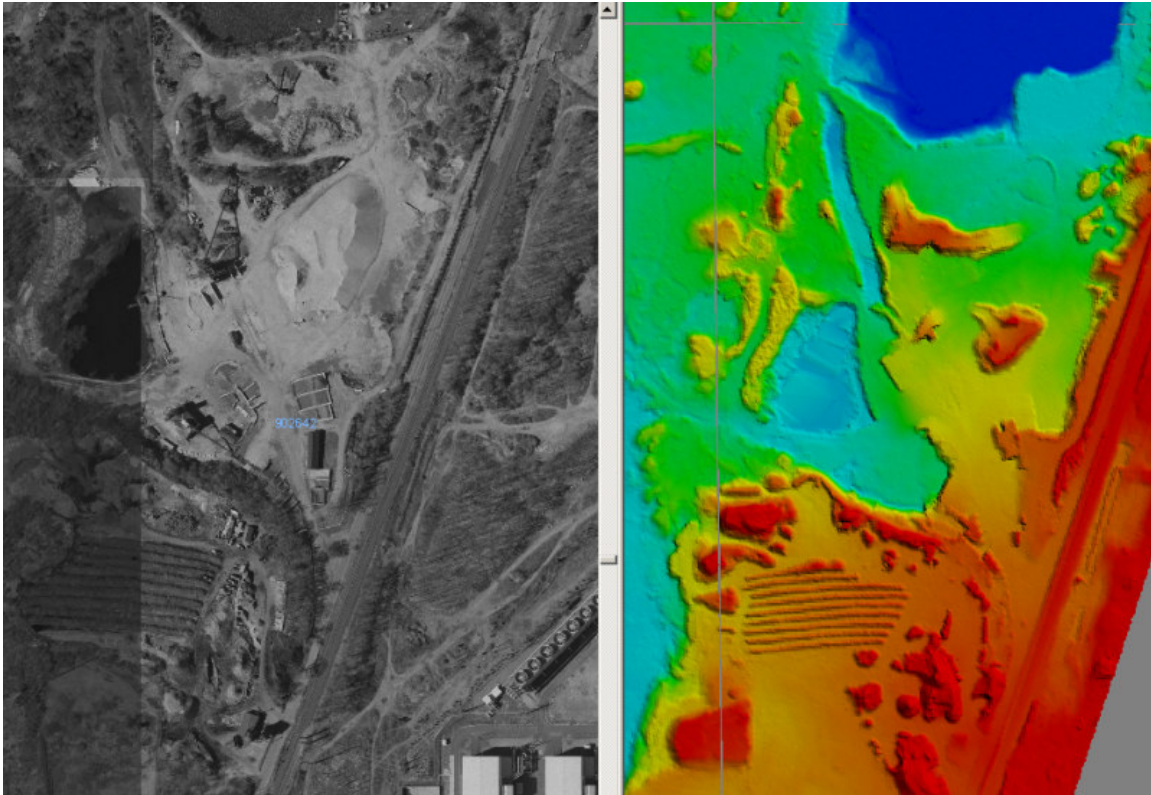
The three types of issues are:

1. Cleanliness of artifacts
2. “Cornrow” effect and noise along scan edges.
3. Bridge removal consistency

The cleanliness of the bare earth data is of excellent quality and meets the requirement of this project. In a few isolated tiles we have found potential buildings or vegetation artifacts most likely due to a misclassification (see Figure 11). Due to the large spectrum of geographic patterns, there are instances where the algorithms erroneously classify the data. However it is evident that these potential areas are relatively small and easily within the specification of being 95% cleaned of artifacts. In this project we encountered a lot of industrial staging areas with soil heaps. It should be noticed that they were not removed from the bare earth model and should be acceptable (see Figure 12).

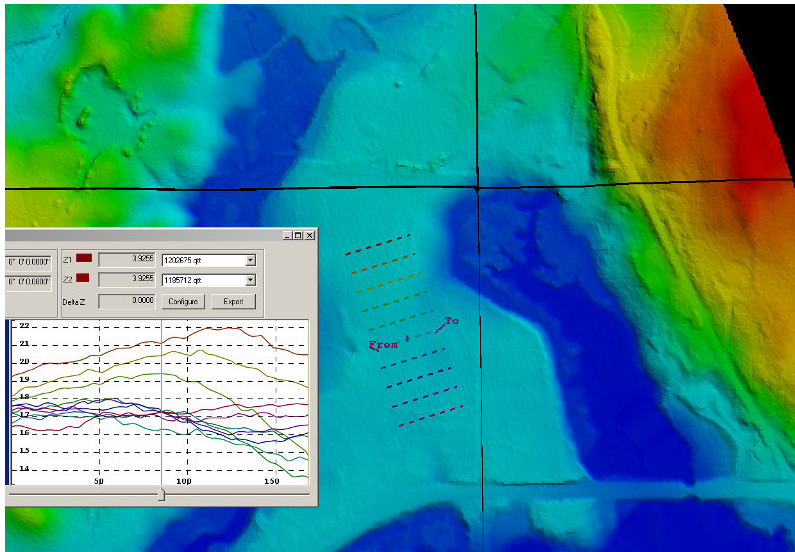






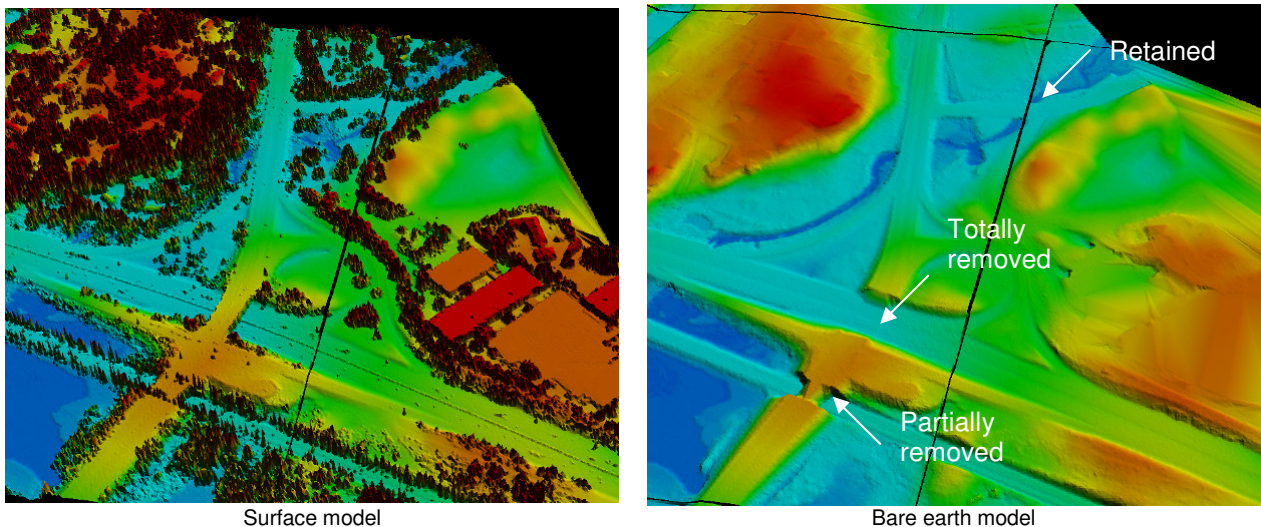
**Figure 12 – Tile 902642 - Soil heaps left in the bare earth (left: orthophoto, right: bare earth model)**

Cornrows were typically seen throughout the project. There are multiple reasons as to why this happens but the end result is that adjacent scan lines are slightly offset from each other. This will give the effect that there are alternating rows of higher and then lower elevations. Although this is common with LiDAR data, as long as the elevation differences are less than 20 cm and the occurrences are minimized, it is acceptable because it is within the noise and accuracy levels. However this also can be an indication that the sensor is mis-calibrated, or offsets exist between adjacent flight lines so each area identified is analyzed. Our review found several instances of the cornrow effect, but the remainder of this effect was within acceptable limits. Figure 13 illustrates a cornrow artifact.



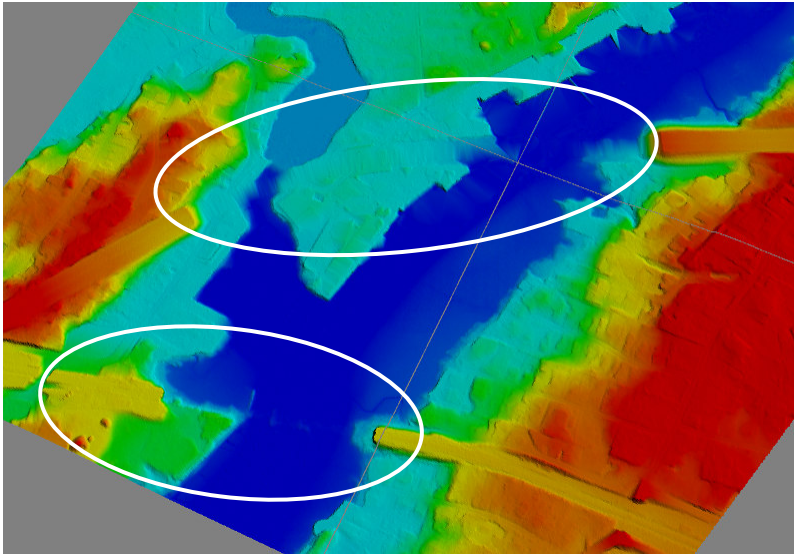
**Figure 13 – Possible corn row artifact**

One minor issue for the bare-earth terrain is the classification of bridges. Some users may require bridges to be removed (classified to non-ground) while others may require them classified as ground. For the user community if this is an issue this is easily remedied because it is clearly identifiable and the data can be reclassified. Figure 14 illustrates various scenarios of bridges partially removed or retained; generally speaking large bridges have been removed even though this was not a specific requirement in the scope of work. Overpasses are also generally removed as in Figure 15.



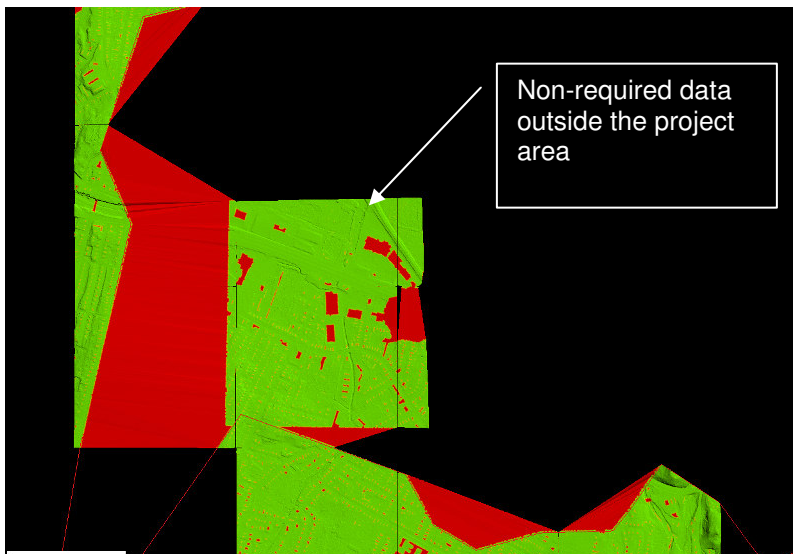
**Figure 14 – Tile 837605: inconsistent bridge editing. Bridges are sometimes totally removed, retained or sometimes portions of the bridge remain in the bare earth terrain.**





**Figure 15 – Tile 765575: Complete removal of overpasses and bridges (ground model)**

Along the project boundary, the tiles are supposed to be clipped, Figure 16 illustrates two tiles not clipped along the polygon delivered with data whereas the adjacent tiles were clipped. This creates what seem to be data voids where data were not actually required. Although it may create confusion, we do not consider this as an issue.



**Figure 16 – Tile 960667 - Non-requested data outside the project boundary (light blue line) apparently causes data holidays (symbolized in red in this point density model)**

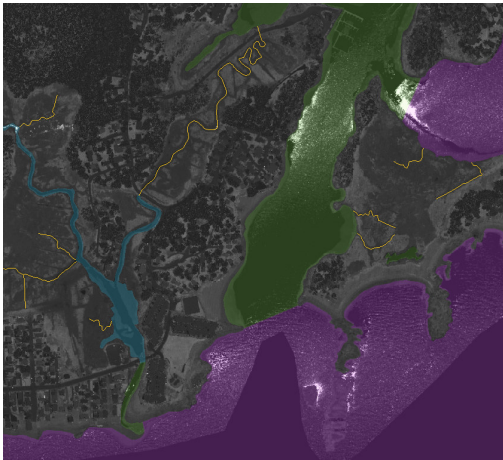
## 4 Topographic data production

### 4.1 Breaklines

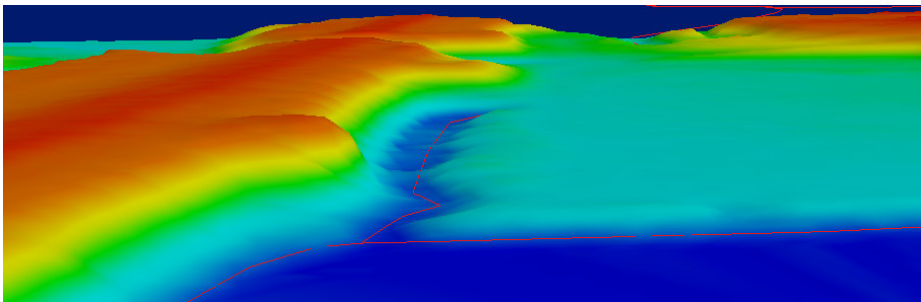
Supplemental 3D breaklines were acquired by Dewberry over this entire mapping area using stereo pairs derived from the LiDAR intensity imagery. Only hydrographic features needed to support the terrain model for hydrology have been considered. Table 3 lists the items available in the delivered shapefiles. The compilation rules can be found as an attached document (CT\_3DBreaklinesData Dictionary.pdf).

**Table 3 – Breaklines acquisition specifications**

File	Item represented	Feature Code
Line feature class	Single Line Feature < 20ft	1
	Hidden Single Line Feature < 20ft	2
	Large Linear Hydrographic Feature > 20ft	10
Polygon feature class	Hidden Large Linear Hydrographic Feature > 20ft	20
	Waterbody with holes	30
	Islands	31
	Coastal Shoreline	40



**Figure 17 – Breaklines with intensity image (coastline-purple, waterbody-green, large hydro-blue, single hydro-orange)**



**Figure 18 – 3D hydro -Breaklines over bare earth model**

The following comments describe in detail what is provided:

- Features are only acquired in mapping area.
- Small ponds or irrigation canals are not acquired.
- Coastline is one polygon with a constant elevation set at the best estimate of the mean high water level and of vegetation limit (0 ft here), whereas the water level seen in the images could be at low tide as illustrated in Figure 19.



**Figure 19 – Detail of a coastline polygon at MHW whereas the actual water shows a lower level**

Several steps of preprocessing have been done to render these features class usable as breaklines in a triangulated irregular network (TIN). The 3 major types of features we used are:

- Small streams lines and adjacent lines for large streams as hard breaklines, with elevation;
- Large river polygons and water bodies to remove the points inside water;
- Waterbodies (lakes, bays, sea) with a constant elevation as hard replace polygon, this means that the polygon outline is used as a hard breakline and the TIN elevation inside the polygon is replaced by the shape elevation.

## **4.2 Contours**

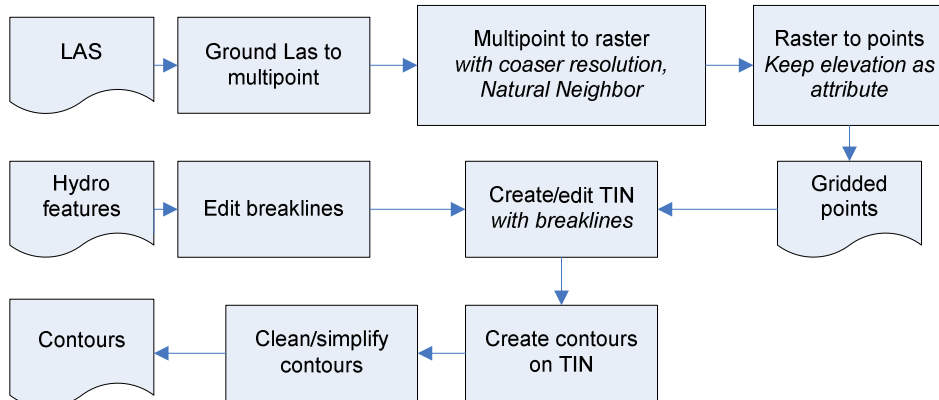
Our goal was to produce engineering grade contour lines at a 2 ft interval. As stated in the scope of work, the emphasis was made on the accuracy of contours as opposed to aesthetically pleasing.

ArcGIS 9.2, 3D analyst was used for the contouring. First hydro features were edited to obtain the breaklines needed to constraint the TIN.

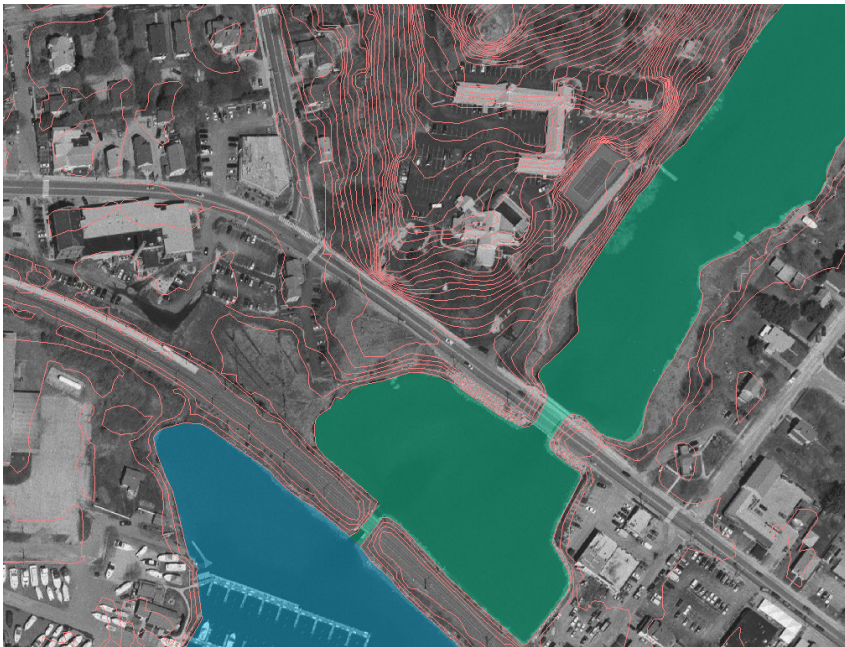
LAS files were then converted to a 3D point vector format usable in ArcGIS (multipoints) with a selection of the ground class only, the points were used to create a raster at a coarser resolution than the source data, i.e. whereas the data have a 3 ft point spacing we used a 15 ft cell size for the raster. This would introduce a smoothing for the final contours while keeping the georeferencing of the lines within an acceptable range. The raster was then exported to a point format (storing the elevation information as an

attribute) usable for the TIN construction. Water points were removed from this point file using the waterbody polygons. These mass points and the breaklines were then used to build a TIN from which 2 ft isolines were computed. Short lines (<150ft, except at the project boundary) and closed contours inside rivers were erased and a final line simplification was applied to clean the contours (summarized in Figure 20). A final quality control was applied to assess the topology consistency of the contour lines (no intersections, no self-intersection, and no dangles except at the project boundary).

The result of this process can be seen in **Error! Reference source not found..**



**Figure 20 – Simplified process flow for contouring**



**Figure 21 – Example of the generated contours with breaklines over orthophoto. Note that the contours follow the bare earth model topography and that bridges were partially removed in the bare earth model.**

## **5 Conclusion**

Overall the data exhibited excellent detail in both the absolute and relative accuracy. The level of cleanliness for a bare-earth terrain is of the highest quality and no major anomalies were found. The figures highlighted above are a sample of the minor issues that were encountered and are not representative of the vast majority of the data which is of excellent quality.

## Appendix A Control points

Connecticut State Plane, North American Datum of 1983  
North American Vertical Datum of 1988, Geoid 2003

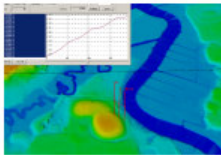
pointNo	e	n	elevation	zLiDAR	LandCoverType	DeltaZ	AbsDeltaZ
605	864465.962	610400.08	4.45	3.97	Open Terrain	-0.48	0.48
1001	957847.23	670674.99	5.76	5.58	Open Terrain	-0.19	0.19
1101	983723.196	657915.56	15.12	14.94	Open Terrain	-0.18	0.18
708	896949.224	635428.93	26.49	26.39	Open Terrain	-0.10	0.10
808	914264.36	641023.41	29.35	29.26	Open Terrain	-0.10	0.10
203	758201.278	568459.23	11.55	11.46	Open Terrain	-0.09	0.09
1302	1052424.09	658892.80	8.45	8.37	Open Terrain	-0.08	0.08
303	786572.066	578077.71	7.47	7.43	Open Terrain	-0.05	0.05
117	969445.462	705690.67	15.79	15.76	Open Terrain	-0.03	0.03
505	839858.693	603394.70	13.87	13.84	Open Terrain	-0.03	0.03
1401	1083987.05	666561.91	33.34	33.37	Open Terrain	0.03	0.03
1603	1176087.21	674816.96	33.04	33.13	Open Terrain	0.09	0.09
2009	1236671.22	690122.33	5.41	5.51	Open Terrain	0.10	0.10
1701	1184348.72	690752.92	126.41	126.53	Open Terrain	0.12	0.12
1501	1139839.99	671003.55	10.46	10.60	Open Terrain	0.14	0.14
905	945128.857	669273.86	7.38	7.54	Open Terrain	0.16	0.16
1201	1022184.07	658594.06	4.92	5.08	Open Terrain	0.16	0.16
1805	1184095.01	751929.63	6.64	6.83	Open Terrain	0.18	0.18
1901	1216767.08	694331.59	54.41	54.64	Open Terrain	0.23	0.23
410	819219.857	600621.06	37.83	38.08	Open Terrain	0.25	0.25
1102	982046.792	660756.86	10.32	10.08	Weeds/Crop	-0.24	0.24
901	949672.469	656129.96	6.76	6.56	Weeds/Crop	-0.20	0.20
803	919182.875	636745.09	6.35	6.26	Weeds/Crop	-0.09	0.09
1301	1054184.01	654358.43	7.11	7.05	Weeds/Crop	-0.06	0.06
1004	962587.405	678426.97	4.88	4.86	Weeds/Crop	-0.03	0.03
701	901090.006	620482.65	8.37	8.36	Weeds/Crop	-0.01	0.01
1806	1187683.25	739021.00	59.11	59.14	Weeds/Crop	0.03	0.03
1207	1025776.04	665391.65	71.62	71.66	Weeds/Crop	0.04	0.04
601	858934.405	606093.49	2.46	2.51	Weeds/Crop	0.05	0.05
1905	1219832.62	693373.62	12.73	12.84	Weeds/Crop	0.11	0.11
1504	1139000.53	676933.19	12.70	12.81	Weeds/Crop	0.11	0.11
2001	1240006.07	684767.06	2.29	2.48	Weeds/Crop	0.19	0.19
503	831802.005	610999.80	5.21	5.40	Weeds/Crop	0.19	0.19
104	965956.872	701024.59	13.84	14.05	Weeds/Crop	0.20	0.20
206	773218.1	562532.70	13.13	13.36	Weeds/Crop	0.23	0.23
1704	1190514.58	682644.82	3.83	4.08	Weeds/Crop	0.25	0.25
1402	1087496.58	663081.23	6.77	7.08	Weeds/Crop	0.31	0.31
1609	1173737.63	671800.56	2.61	3.10	Weeds/Crop	0.49	0.49
305	791636.637	577508.78	5.99	6.73	Weeds/Crop	0.74	0.74
401	818733.754	596776.31	4.18	4.94	Weeds/Crop	0.76	0.76
1015	961898.121	677197.89	7.65	7.46	Forest	-0.19	0.19
508	839494.625	601928.85	14.35	14.25	Forest	-0.10	0.10
712	898009.361	617264.96	25.69	25.60	Forest	-0.10	0.10
813	916862.676	641219.40	28.59	28.50	Forest	-0.09	0.09
211	773123.039	564782.14	7.27	7.18	Forest	-0.09	0.09
114	969128.429	694849.29	30.92	30.87	Forest	-0.05	0.05
913	943955.54	673679.69	11.42	11.37	Forest	-0.05	0.05
415	822624.278	592670.90	8.72	8.68	Forest	-0.04	0.04
2010	1239477	686532.86	33.73	33.73	Forest	0.00	0.00
315	787927.879	576799.01	6.33	6.34	Forest	0.00	0.00
1916	1217076.71	703923.71	4.97	5.02	Forest	0.05	0.05

1610	1174624.17	671652.24	31.45	31.51	Forest	0.07	0.07
1108	985390.343	661874.45	7.50	7.58	Forest	0.07	0.07
1408	1065521.98	660845.99	12.31	12.41	Forest	0.10	0.10
1317	1063852.76	661752.62	14.81	14.93	Forest	0.12	0.12
1215	1018873.48	663883.11	17.19	17.33	Forest	0.14	0.14
1809	1185513.18	739930.43	76.66	76.88	Forest	0.22	0.22
1713	1197067.68	683881.16	9.44	9.68	Forest	0.24	0.24
1514	1139803.27	675866.22	16.43	16.71	Forest	0.28	0.28
615	857181.944	606949.07	5.54	5.99	Forest	0.45	0.45
209	768116.701	577390.57	17.84	17.32	Urban	-0.52	0.52
805	932151.067	643883.29	19.49	19.14	Urban	-0.35	0.35
1206	1019445.26	665780.55	23.94	23.70	Urban	-0.24	0.24
409	817315.499	604015.24	28.06	27.82	Urban	-0.24	0.24
604	862472.949	614524.30	8.67	8.44	Urban	-0.23	0.23
1305	1060382.41	662640.60	22.97	22.75	Urban	-0.22	0.22
709	898858.695	634021.86	15.95	15.79	Urban	-0.17	0.17
1103	980396.864	661912.70	32.61	32.47	Urban	-0.14	0.14
1005	957773.114	675725.63	17.76	17.64	Urban	-0.12	0.12
1403	1091832.44	665119.18	21.72	21.61	Urban	-0.11	0.11
902	943002.685	659464.27	15.94	15.84	Urban	-0.09	0.09
2008	1231429.72	682624.15	4.91	4.92	Urban	0.02	0.02
504	831467.386	612533.33	8.87	8.93	Urban	0.06	0.06
116	973691.032	713381.25	37.06	37.12	Urban	0.06	0.06
1506	1150038.58	678704.43	19.83	19.96	Urban	0.13	0.13
1710	1192221.21	687506.54	17.06	17.20	Urban	0.14	0.14
1804	1181279.81	752011.06	93.81	93.98	Urban	0.17	0.17
304	792315.499	579334.78	7.59	7.79	Urban	0.20	0.20
1902	1216699.63	697746.44	19.54	19.80	Urban	0.26	0.26
1604	1178421.2	674073.36	5.23	5.49	Urban	0.27	0.27

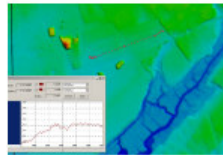


## Appendix B Contact sheets of potential qualitative issues

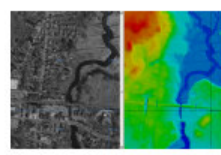
Connecticut-Screen Shots of Potential Issues



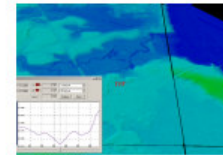
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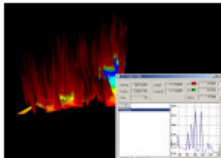
1057660\_someNoise\_qttGound.png



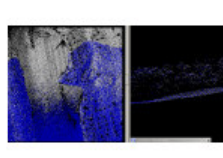
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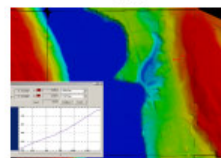
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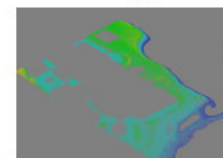
1147695\_spikes40ft\_fpcQtt.png



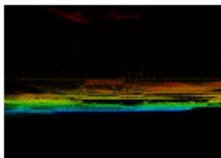
1152692\_comRows2flightLineOverlap\_FpcCrossSectionByFlightLine.png



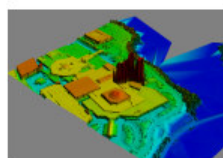
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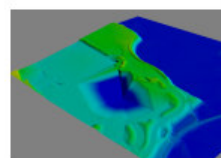
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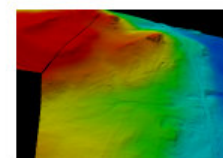
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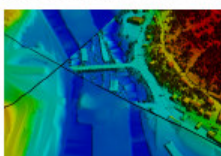
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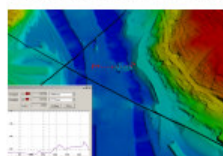
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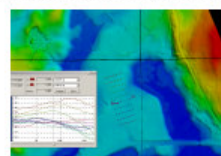
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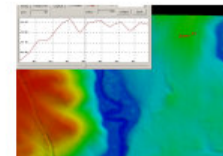
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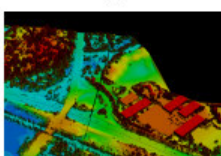
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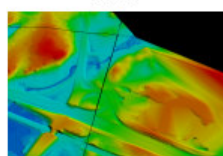
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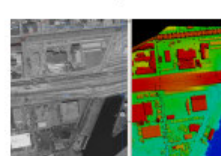
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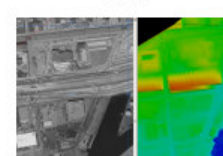
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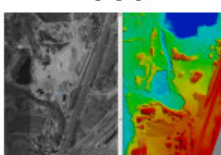
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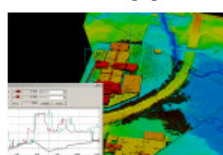
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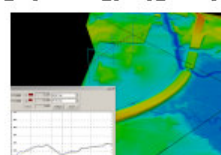
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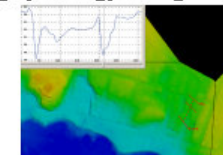
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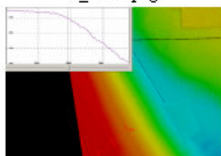
920645\_buildingArtifacts\_partialBridgeRemoval\_qttFcp.png



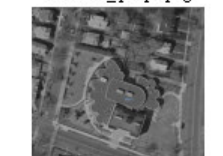
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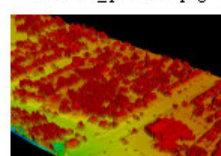
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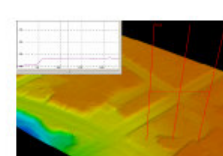
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940675\_buildingArtifact\_ortho.png



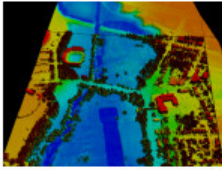
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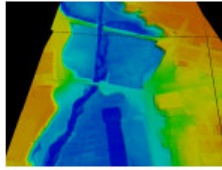
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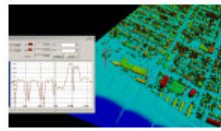
### Connecticut-Screen Shots of Potential Issues



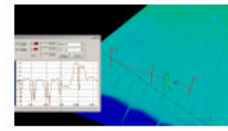
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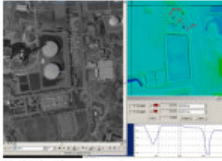
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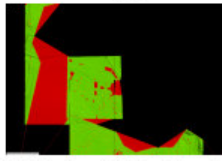
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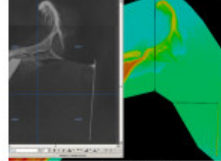
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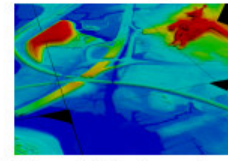
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960667\_dataOutsideProjectBoundary\_qttGroundDensity.png



962657\_disappearingSeaWall\_qttGroundOrtho.png



962677\_partialBridgeRemoval\_qttGround.png